International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 3, Jun 2019, 637-644

COMPUTATIONAL ANALYSIS OF MIXING IN SCRAMJET COMBUSTOR USING CROSS FLOW INJECTION TECHNIQUE

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ABSTRACT

The prime issue in supersonic combustion is proper mixing within short duration of time since the flow is supersonic. Computational study has been performed to analyze the mixing of air and fuel using cross flow injection technique. Cross flow injection is performed by placing the fuel injectors on the walls of the scramjet engine which is perpendicular to the flow. To enhance the mixing of fuel and air, cavities were introduced. The flow recirculation inside the cavity will enhance the mixing and combustion. The fuel injectors were placed just upstream of the cavity. Analyses were done by changing the injection angle configurations. The air is allowed to enter at different Mach numbers and the changes were analyzed using ANSYS software packages. The roles of cavity cross flow injection, pressure, temperature, velocity and Mach umber variation were examined in this study and the obtained results were compared between various configurations.

KEYWORDS: Cross Flow Injectors, Mach Number, Cavity, Ramp Angle & Combustion

Received: Mar 14, 2019; **Accepted:** Apr 04, 2019; **Published:** May 03, 2019; **Paper Id.:** IJMPERDJUN201970

Original Article

INTRODUCTION

It is hard to achieve efficient fuel/air mixing inside the supersonic combustor because of extremely short residence time of air. This is an important issue while considering the reduction of skin friction drag and the combustor length. At high Mach numbers, the compressibility effects also affect the mixing rate. There are two major concepts for fuel injection in supersonic combustors:

- Wall injectors: Where fuel is injected through the wall normal to the flow or by ramps mounted into the wall,
- Strut injectors: Which are mounted at the channel axis and directly inject the fuel into the core of the air stream.

The main advantage of employing the wall injector is we could obtain a good near field mixing. On the other hand this wall injection system causes a significant blockage of the flow. This results in irreversible condition due to shock waves and thrust losses. Another disadvantage is that the fuel jet penetration is insufficient for real size combustors. Wall injectors are easy to manufacture, so easy to cool, and, more advantageous in case of staged injections, there is no losses in total pressure if they are switched off. But in case of strut injectors, the injectors may not be removed from the flow field if there is no injection needed. The injected hydrogen should perform as a

coolant for the strut. There is an alternative to physical ramp injectors which is aero ramps which have a similar physical behavior but power losses will be low when compared with the struts. This may become an important consideration at high flight Mach numbers. Mixing enhancement techniques were needed due to the limited mixing capabilities of parallel high speed streams. This can be achieved either by creating stream wise vorticity or by creating shock waves. Because of the relatively low air static temperatures, the axial strut injector induces weak shock waves and small recirculation areas downstream of the strut. This project is mainly to avoid the normal shock by means of transverse injection and the recirculation is enabled by means of cavity with fuel injected upstream of the cavity. This cavity will also provide a continuous ignition point or the flame holder with fewer drops in pressure, and hence combustion can be sustained. The main advantage of employing cavity behind the wall injectors is there will be lesser drag associated with flow separation. It was observed that the mixing efficiency and combustion was greatly enhanced by constructing cavities behind the fuel injection points. Because of the mass and heat movement along the shear layer and inside the cavity are greatly increased. Based on the free stream conditions, the ignition time determines the depth of the cavity and the length of the cavity has to be chosen in such a way to sustain a suitable vortex to provide sufficient mixing inside the cavity. The mixing and ignition of fuel and free stream air requires sufficient time. In this project a scramjet combustor is constructed with cavity and the injection was done by wall injection techniques and efforts were made to observe how the mixing gets enhanced when compared with the normal injections. Analyses were done at different fuel injection angles.

MODELLING AND SIMULATION

There are different methods of injection techniques were availed for scramjet engines. Injection techniques with better mixing capability should be selected to get better combustion efficiency. In the present day computation fluid dynamics is used to analyze the injection techniques and the mixing pattern inside the scramjet engine using different categories of injection units. Initially the model was designed using CATIA V5 software. In this study, a duct was considered at a length of 223.5 m. Injectors were placed at a distance of 7.3 m. The injectors were placed at the base of the duct and the upper surface of the duct. The diameter of each duct is 1mm. 18 injecting holes were placed on each surface of the duct. To enhance the mixing of the fuel and the fluid a cavity is placed at a distance of 58.8m from the inlet. The designed model is shown in the figure.

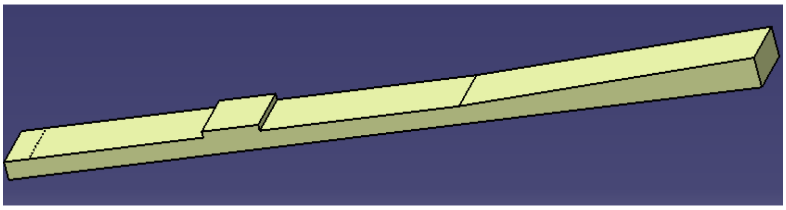


Figure 1: Scramjet Model with Cavity Configuration

Meshing

Meshing was done by ICEMCFD package. Meshing of the model was done with triangular meshes. The boundaries were defined as inlet, outlet, and wall, symmetry and fuel inlet. To attempt good quality mesh, the resolution of mesh at all important areas was varied. The computational mesh at this level of refinement is to reach the limit of grid independence. After meshing, required boundary conditions were defined to start the simulations.

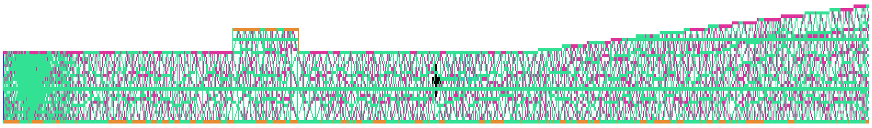


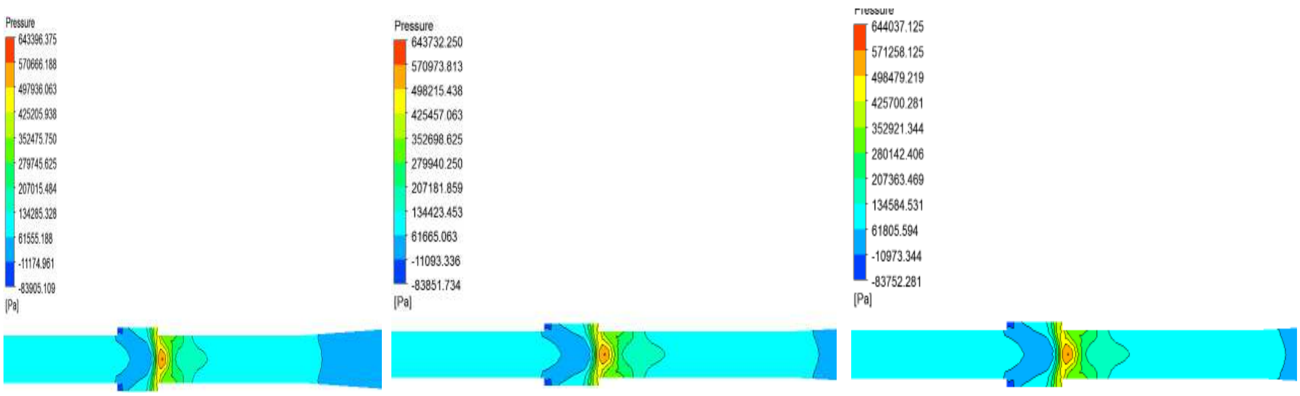
Figure 2: Meshed Model

RESULTS AND DISCUSSIONS

Analyses were done by changing the injecting angles. The results obtained by varying the injecting angles were observed and recorded here. Input values were given and the iterations were limited for 100 in numbers and were plotted. We stopped our analysis at once our iterations get converged. Static pressure contour, temperature, contour, velocity contour and the flow pattern were observed and recorded here. The various plots of properties such as static temperature, static pressure along the length of the combustor for the different injecting angles are also recorded. The static pressure contour and the density contour will help us to understand about the formation of shock wave or the disturbance caused because of the injecting liquid.

At Mach number M=0.2

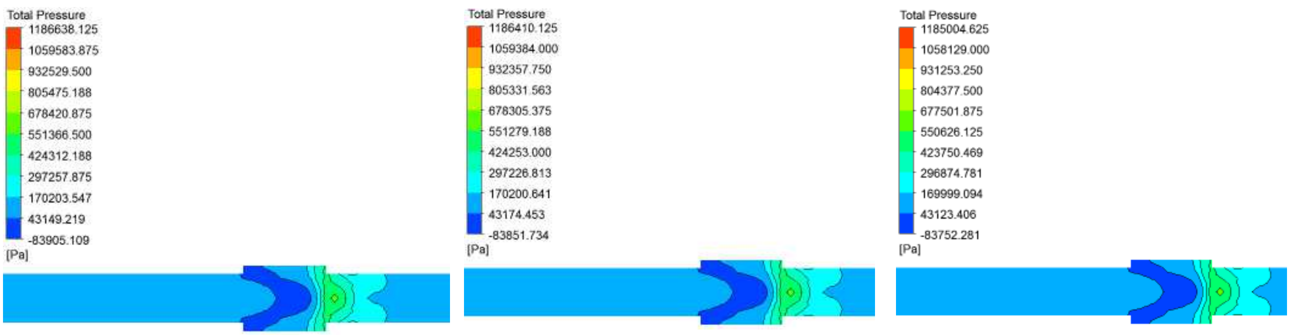
Pressure Contour for Various Injection Angles and at Mach=0.2



45 degree **60 degree** **90 degree**

Figure 3: Pressure Contours for Different Injection Angles at Mach 0.2

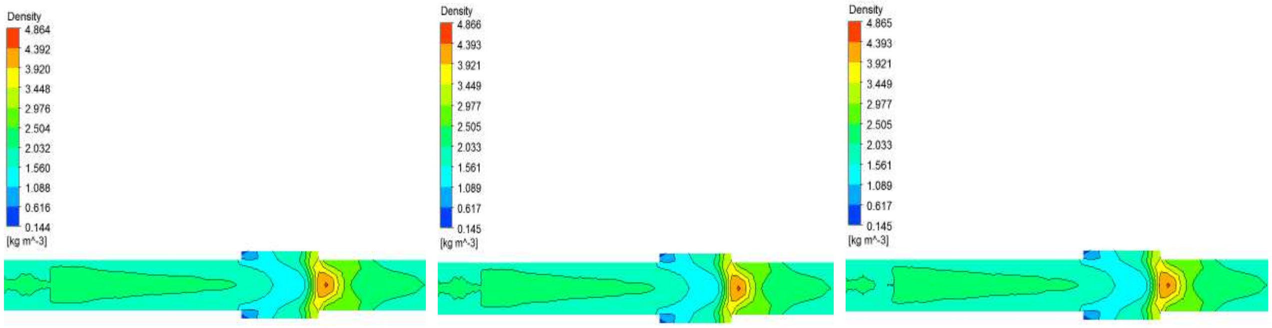
Total Pressure Contour at Mach Number 0.2 and for Various Injection Angles



45 degree **60 degree** **90 degree**

Figure 4: Total Pressure Contour for Different Injection Angles at Mach 0.2

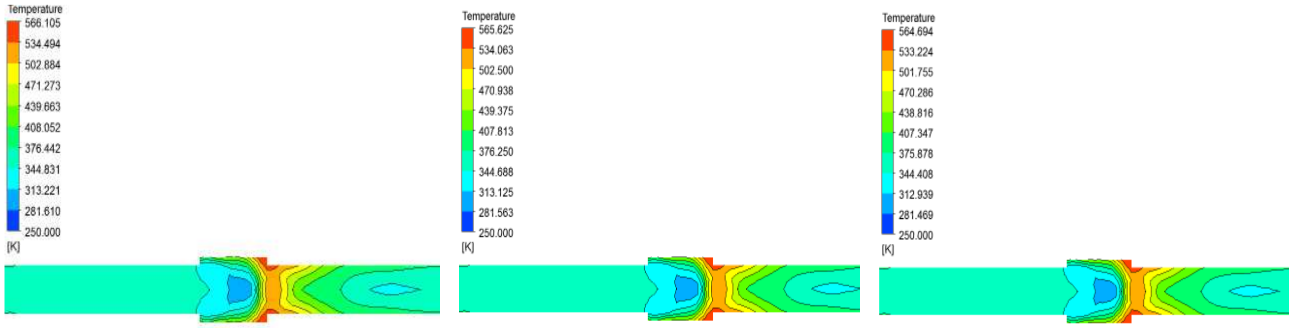
Density Contour at Mach Number 0.2 and for Different Injection Angles



45 degree **60 degree** **90 degree**

Figure 5: Density Contour for Different Injection Angles at Mach 0.2

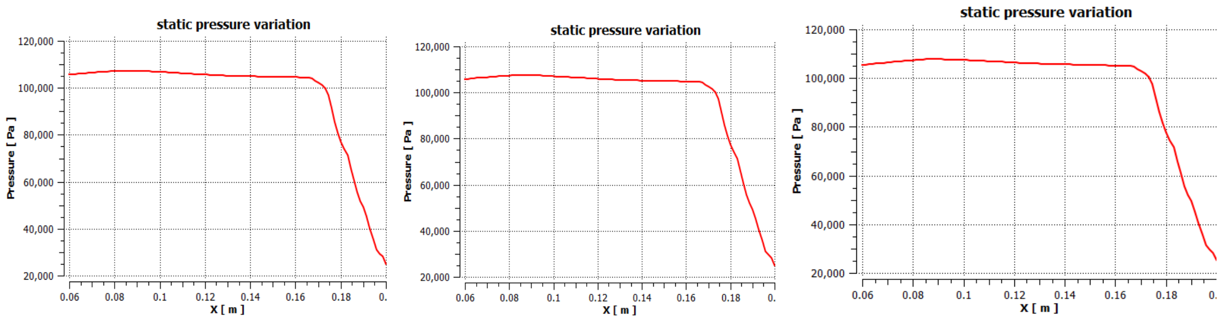
Temperature Contour at Mach Number 0.2 for Different Injection Angles



45 degree **60 degree** **90 degree**

Figure 6: Temperature Contour for Different Injection Angles at Mach 0.2

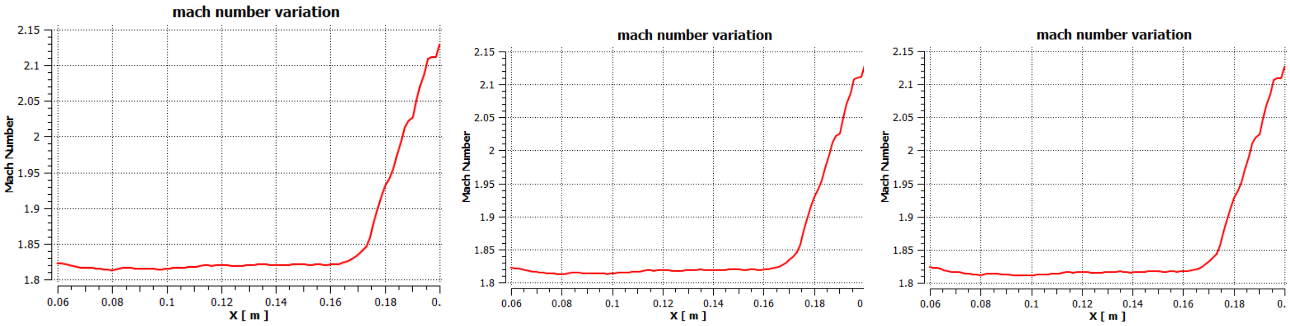
Static Pressure Plot at Mach Number 0.2 and for Various Injection Angles



45 degree **60 degree** **90 degree**

Figure 7: Static Pressure Plot at Various Injection Angles at Mach 0.2

Mach Number Plot at Mach Number 0.2 and for Various Injection Angles

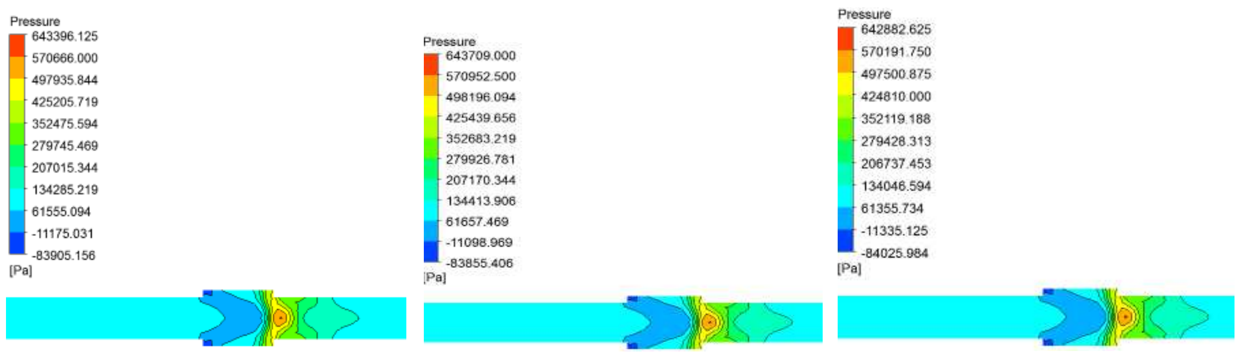


45 degree **60 degree** **90 degree**

Figure 8: Mach Number Plot at Various Injection Angles at Mach 0.2

At Mach Number M=0.3

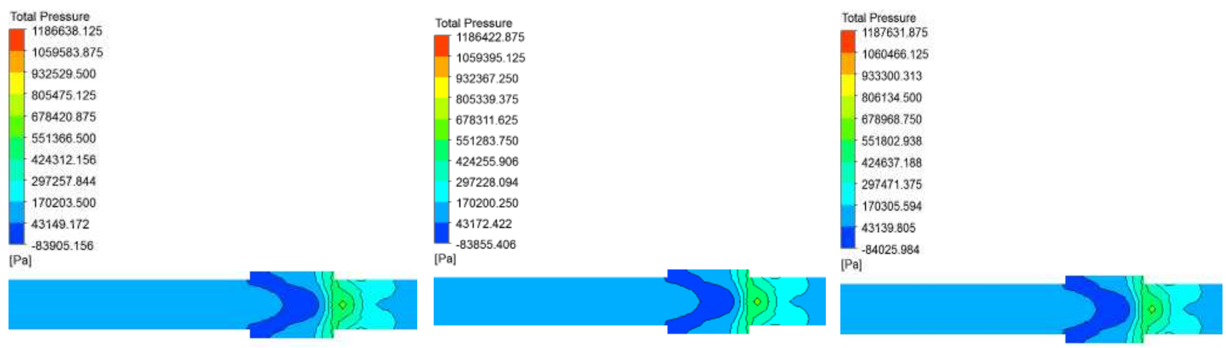
Pressure Contour at Mach Number 0.3



45 degree **60 degree** **90 degree**

Figure 9: Pressure Contours for Different Injection Angles at Mach 0.3

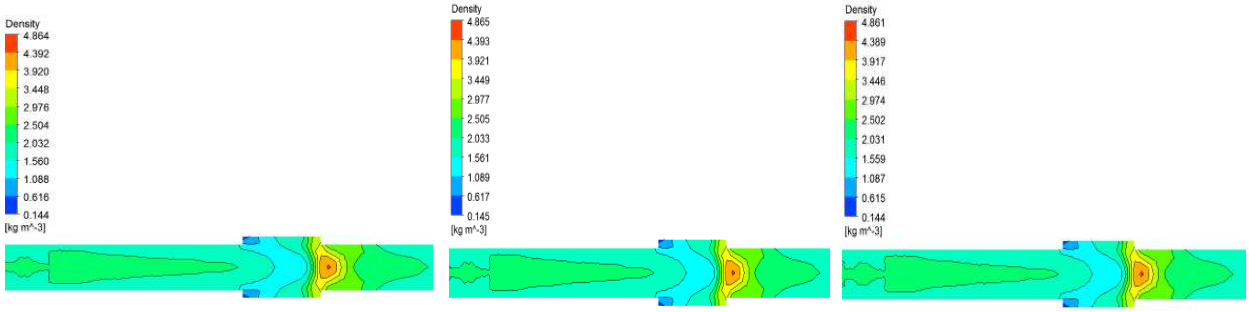
Total Pressure Contour at Mach Number 0.3 and for Various Injection Angles



45 degree **60 degree** **90 degree**

Figure 10: Total Pressure Contour for Different Injection Angles at Mach 0.3

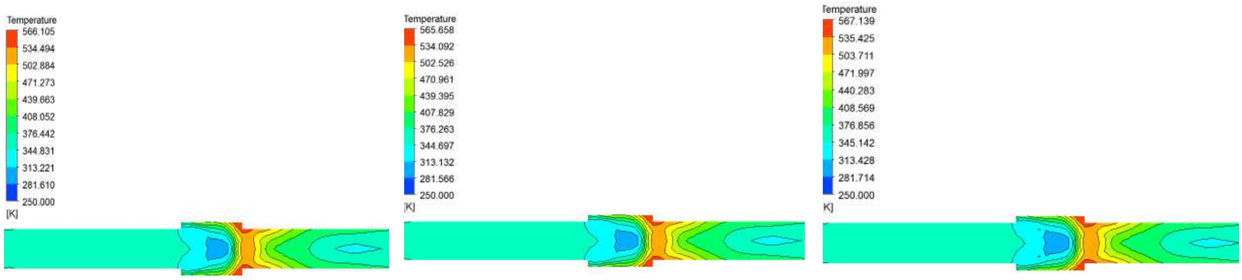
Density Contour at Mach Number 0.3 and for Various Injection Angles



45 degree **60 degree** **90 degree**

Figure 11: Density Contour for Different Injection Angles at Mach 0.3

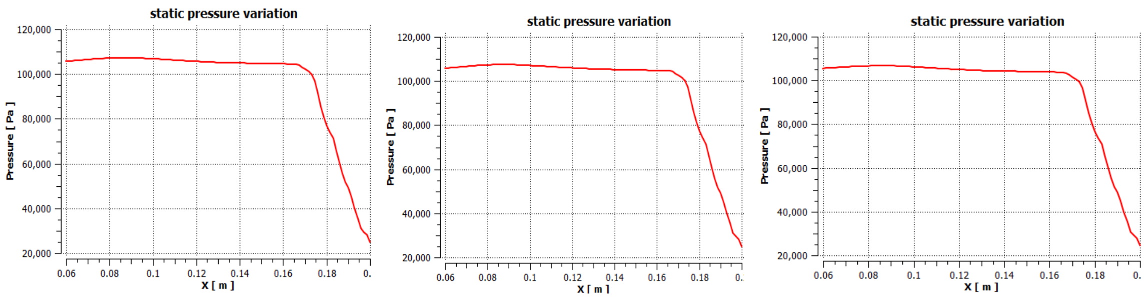
Temperature Contour at Mach Number 0.3 and for Different Injection Angles



45 degree **60 degree** **90 degree**

Figure 12: Temperature Contour for Different Injection Angles at Mach 0.3

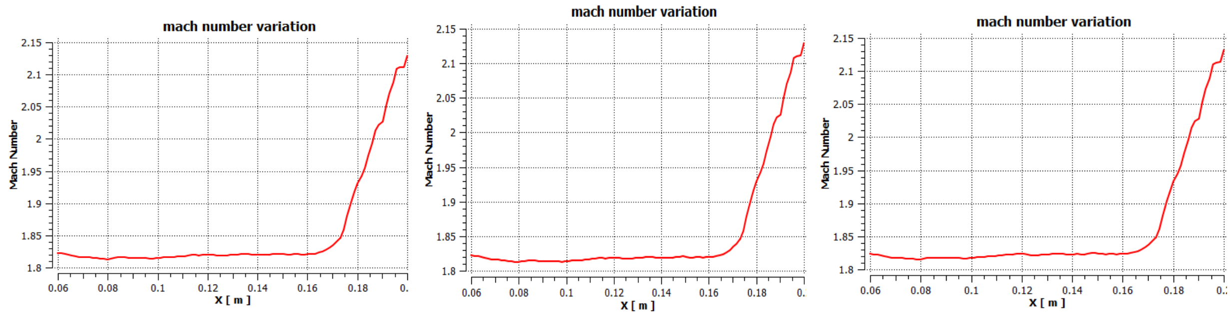
Static Pressure Plot at Mach Number 0.3



45 degree **60 degree** **90 degree**

Figure 13: Static Pressure Plot for Different Injection Angles at Mach 0.3

Mach Number Plot at Mach Number 0.3



45 degree **60 degree** **90 degree**

Figure 14: Mach Number Plot for Different Injection Angles at Mach 0.3

CONCLUSIONS

From the above analysis, it is observed a rich mixing pattern was enhanced by employing the wall injection techniques along with the cavity. The analyses were done at different injection angles and the results were discussed above. The air is allowed to enter at a Mach of 1.5 and the fuel is allowed to enter at a Mach of 0.3 and 0.2. A high axial velocity is obtained which is indicative of high thrust production. Also, the shock formed is also weaker. So we could achieve better flame holding because of the wall injector coupled with cavity. In future, hypersonic combustion systems will be more and more important due to the increasing human need of high speed and less travel time. Since the mixing time for fuel in the scramjet combustor is very less. So newer and better injection systems need to be developed to enhance fuel-air mixing and reduce ignition delay period, thereby we can increase both combustion efficiency and thrust.

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